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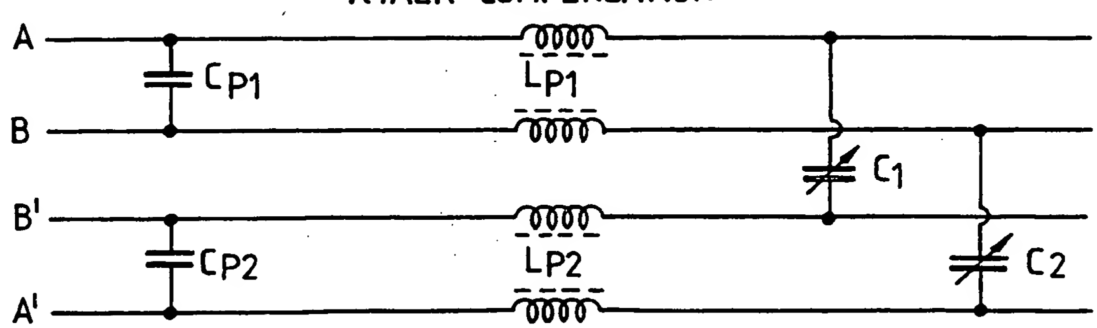
EQUIVALENT ELECTRICAL CIRCUIT FOR LINES AA' BB' WITH FIRST ORDER XTALK COMPENSATION



(57) Abstract

Apparatus and methods for cancelling inherent crosstalk introduced in communications data connectors (10, 20) involve the deliberate introduction of compensatory crosstalk using crosstalk compensation means, such as tuned capacitances (C_1, C_2) to provide a path for the compensatory crosstalk.

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APPARATUS AND METHOD FOR CROSSTALK CANCELLATION IN DATA CORRECTORS

The present invention relates to methods and apparatus for crosstalk compensation. The invention has particular application to the cancellation of crosstalk in data connectors, and more particularly, in connectors used in communications networks.

The problem of crosstalk between signal lines causing signal degradation and errors in data transmission is well known. This problem is exacerbated in typical data connectors, where signal lines are necessarily constrained to be close together, often with reduced shielding. As data is increasingly transmitted at ever higher rates, the problem is further compounded. For example, the conventional RJ-45 data jack commonly used in the telecommunications industry, has been found to have at best a level of crosstalk attenuation which is at least 8dB less than that demanded in the latest performance standards for data communication components. New connector designs have been proposed with improved crosstalk characteristics. However, these would not be compatible with existing connectors.

The present invention is directed towards providing ways to improve crosstalk attenuation, which are potentially applicable to connectors used in data communications.

According to a first aspect of the present invention a communications data connector comprising a first and second signal lines for carrying differential pulse coded data signals and at least one further signal line is characterised in that the connector further comprises crosstalk compensation means provided between the first signal line and the further signal line; the crosstalk compensation means being arranged to enable

the introduction of compensatory crosstalk from the first signal line to the further line to counteract inherent crosstalk otherwise introduced between the second signal line and the further line.

By providing crosstalk compensation means to introduce crosstalk deliberately from one signal line to compensate for inherent crosstalk otherwise introduced from a second line into a further line it has been found that overall crosstalk attenuation can be significantly improved.

Generally, the crosstalk compensation means will be selected or adapted to cancel substantially any inherent crosstalk under normal operating conditions.

Conveniently, according to a second aspect of the invention, for a communications data connector having first and second signal lines and at least one further signal line, a method of compensating for inherent crosstalk introduced between the second line of the pair and the further line, comprises the steps of: assessing parameters characteristic of the inherent crosstalk between the second line and the further line under desired operating conditions; providing, on the first line, a complementary signal, matching, but of opposite polarity to the signal on the second line; and providing a crosstalk compensation path between the first and the further lines to enable the introduction of compensatory crosstalk from the first line to the further line to counteract the inherent crosstalk.

Following this procedure allows the crosstalk compensation means (or path) to be appropriately selected to provide a desired level of cancellation of the inherent crosstalk.

Conveniently, the crosstalk compensation can be introduced by positioning a section of the first line of

the pair in sufficiently close proximity to the further line over an appropriate length selected to enable the introduction of the desired level of compensatory crosstalk.

This is a relatively simple solution which avoids the need for additional components to introduce the compensatory crosstalk. Generally, it will rely on introducing a controlled degree of stray capacitative coupling between the first and further lines to achieve the required result.

Where the connector is a wall mounted data jack unit, for example, in which a connector socket is usually mounted on a printed circuit board, the crosstalk compensation can simply be provided by printing the relevant tracks, corresponding to the signal lines, closely enough over an appropriate length to provide the desired level of compensation.

Alternatively, the connector may comprise a length of data cable carrying the signal wires and deliberately manufactured to introduce a predetermined level of crosstalk compensation between specified signal lines. Such a connector could readily be inserted into existing networks to provide upgraded crosstalk attenuation.

Alternatively, again, the crosstalk compensation may be achieved by including a component with an appropriate reactive element to introduce a controlled level of compensatory crosstalk. Generally, the reactive element will be capacitative. For typical, existing data connectors, such as the well known RJ-45, the capacitance will range from a few picofarad up to 25-30pF, according to the degree of compensation desired, and usually in the range 1-20pF and most probably 2-15pF, for optimum cancellation of inherent crosstalk in each connector.

Again, the crosstalk compensation can be conveniently provided in existing types of data connector, simply by including a reactive element such as a suitable capacitor selected to provide the desired compensatory crosstalk between the appropriate signal lines in the connector itself.

For flexibility, the reactive element will be tunable. This allows the crosstalk compensation to be optimally adjusted in situ to suit the relevant operating conditions.

In any case, the reactive element can be provided, for example, in a wall mounted data jack unit; in a data plug for connecting to the socket of such a data jack unit; or in a special plug-in module designed to be inserted in-line in an existing network, as proposed for the length of special data cable described above.

The invention is of particular applicability for data connectors which include two or more pairs of signal lines for carrying differential pulse coded data. In such connectors, crosstalk compensation can be provided from each line of a first pair to the corresponding line of a second pair to counteract any inherent crosstalk otherwise introduced from each line of the first pair to each other line of the second pair. According to the level of the inherent crosstalk between different pairs, the invention can be extended by analogy to enable the introduction of compensatory crosstalk between several pairs of signal lines in multi-line connectors.

In circumstances where the inherent crosstalk is predominantly in one direction (ie. from one line of a pair into a further line, but not significantly vice versa), the crosstalk compensation is similarly arranged to be predominantly uni-directional (from the other line

of the pair to the further line) through appropriate circuit design of the crosstalk compensation means using additional components where necessary.

Aspects and embodiments of the invention will now be described in detail and by way of example with reference to the accompanying drawings, in which:

Figure 1 is a schematic of an experimental arrangement for implementing a method according to the invention;

Figure 2 includes schematic illustrations of a typical data jack connection together with equivalent electrical circuits with and without crosstalk compensation;

Figure 3 is a graph comparing the crosstalk attenuation of a data connector with and without crosstalk compensation;

Figure 4 illustrates schematically various examples of connectors according to the invention;

Figure 5 is an exploded diagram of a data connector according to the invention;

Figure 6 is a schematic diagram of a data cable with connectors as shown in Fig 5 adapted to provide crosstalk compensation; and

Figure 7 is a schematic diagram of part of a printed circuit board for a connector according to the present invention.

For measuring the crosstalk characteristics of a data jack connection, the apparatus in Fig 1 is used. A connection, comprising a plug 10 and a socket 20, is connected to two pairs of signal lines 30,40. The signal lines 30,40 are themselves connected via respective impedance-matching baluns 35,45 to the transmit, T_x, and receive, R_x, terminals of a network

analyser and S parameter test set 50 (in this example, an HP8753C Analyser and HP85047A Test Set are used).

The analyser 50 is connected to provide graphical output to a plotter 55 (in this case an HP7475A). To ensure that only crosstalk arising in the connection 10, 20 is measured, an earthed copper screen 60 is positioned between the signal line pairs 30, 40, which are separated immediately out of the plug 10. Each line pair 30, 40 is terminated by a respective impedance 31, 41 chosen to match the characteristic impedance of the data network in which the connection 10, 20 is used.

In this example, conventional RJ-45 8-line communications data plug and socket connectors 10, 20 are used. Fig 2(a) illustrates the standard signal line pairing for connectors of this type.

Proposed future crosstalk attenuation standards for data communications connectors are expected to require around -55dB attenuation at 16MHz (or around -58dB at 10MHz) between the worst pair combinations. With the signal line arrangement of the RJ-45, the worst pair combinations are between lines B, A, A' and B' as shown in Fig 2(a). For convenience, therefore, only these signal lines are shown in the remaining Figures and only crosstalk between these signal lines is analysed in the experimental arrangement of Fig 1.

To analyse the crosstalk characteristics, the network analyser and test set 50 is set up with the following parameters:

Mode	Transmission (S_{21}) on lines AA'
Send Power	+20dBM
I. F Bandwidth	100Hz
Start Frequency	300kHz
Stop Frequency	30MHz
Sweep	Logarithmic
Vertical Scale	dB
Characteristic impedance	50 Ω

The resulting near-end crosstalk attenuation (NEXTA) is measured for lines BB'.

A plot of NEXTA for the basic unmodified connectors 10,20 is shown by curve (1) on the graph of Fig 3. From this, it can be seen that the crosstalk attenuation of -47dB at 10MHz falls well below the requirement of the anticipated future standards. The inherent crosstalk arises in these connectors primarily from stray capacitances and, at higher frequencies, stray inductances as well. Fig 2(b) shows the equivalent electrical circuit with stray parasitic capacitances C_{P1}, C_{P2} and inductances L_{P1}, L_{P2} between lines AB and B'A', respectively.

The present invention arises from the appreciation that it is possible to provide a direct compensation for this inherent crosstalk in data connectors by deliberately introducing further complementary crosstalk from those lines of the signal line pairs which would not normally significantly influence each other. The invention takes advantage of the fact that data communications systems frequently transmit data using complementary signals, such as by differential pulse code transmission, so a complementary signal which can provide compensatory crosstalk is usually readily

available and need not generally have to be specially provided.

The equivalent electrical circuit for one example embodiment according to the invention is shown in Fig 2(c). As illustrated, this embodiment is characterised by the deliberate introduction of additional, compensatory crosstalk paths via tunable capacitances C_1 and C_2 between signal lines A and B' and signal lines B and A' respectively. With this arrangement, using differential pulse code signals on the signal line pairs AA' and BB', first order compensatory crosstalk is provided to counteract the inherent crosstalk otherwise introduced by the parasitic, stray capacitances and inductances C_{P1}, C_{P2}, L_{P1}, L_{P2} in the connectors.

To maximise the crosstalk attenuation, the compensatory capacitances C_1, C_2 are tuned to minimise the measured crosstalk at a desired frequency. The curve (2) plotted on the graph of Fig 3 shows the improved crosstalk attenuation which can be achieved when the compensatory capacitances are tuned in this way. In the example shown, at 10MHz the attenuation has improved from -47dB to -73dB, which is better than the proposed future standards are presently likely to demand. It is possible to achieve similar results using a single compensatory capacitance (C_1 or C_2) alone. However, in this case a higher individual capacitance value, approximately double that when two capacitances are used, is generally required. The single capacitance arrangement also has the disadvantage that relatively large common mode currents may be generated, which may exceed permissible levels set in the appropriate electromagnetic compatibility (EMC) regulations. Note that the effect of non-capacitive crosstalk at higher

frequencies can be seen in the knee in curve (2) around 7-8 MHz. It may be possible to reduce this effect by providing compensatory crosstalk using inductance in addition to capacitances.

Whilst it is possible to select the compensatory capacitances by tuning to maximise the crosstalk attenuation, for practical purposes, alternative methods may also be used. One such method, which has been found to give acceptable results, is simply to measure the inherent, parasitic capacitances (and inductances if operating at higher frequencies) which exist in the data connectors under test. These parameters will indirectly provide a measure of the likely level of inherent crosstalk at a given frequency.

The compensatory capacitances (and inductances, if desired, at higher frequencies) are then simply chosen to match the corresponding inherent parasitic impedances whose crosstalk is to be counteracted. For the connectors whose test results are shown in Fig 3, the measured, inherent capacitances C_{P1} = 12.8pF, C_{P2} = 13.1pF. Tuning for maximum attenuation at 10MHz gave values for C_1 and C_2 of 13pF.

However, connectors vary in their characteristics, and parasitic capacitances in the range 1pF-30pF may typically be measured. More commonly, the range is 1-20pF, with examples found frequently at 2pF-13pF at 10MHz.

The crosstalk compensation can be achieved in various alternative ways. Fig 4 illustrates a number of possible alternative embodiments within the scope of the present invention.

Instead of using discrete components to provide the compensatory crosstalk, this can be done by the calculated introduction of compensatory parasitic

coupling as shown in Fig 4(a). In this example, the signal lines are repositioned to provide compensatory crosstalk via parasitic coupling over length l_1, between lines B', A' and over length l_2 between lines B, A'. Conveniently, this is achieved, in the example shown, by suitable circuit layout on the printed circuit board (PCB) 25 in the socket connector 20. In this example the different compensatory, parasitic coupling reflects differences in the inherent crosstalk characteristics between lines AB and lines B'A' of the connectors in the absence of the compensation arrangements.

Fig 4(b) illustrates an embodiment where the compensation is provided by discrete, tunable capacitances C_1, C_2 mounted on the PCB 25 of the socket connector 20. This is a practical, general purpose arrangement which allows the level of compensation to be tuned in situ.

Fig 4(c) illustrates a similar arrangement where fixed compensatory capacitances C_1, C_2 are mounted in the plug connector 10. This arrangement is particularly useful for compensating for inherent crosstalk in terminal equipment leads. Providing terminal equipment with crosstalk compensation built-in to the equipment leads in this way eliminates one possibility for degradation of system performance when equipment is interchanged. Analysis by the inventor has found that the amount of crosstalk inherent in a plug/socket combination (such as the conventional RJ-45 connection) is very variable even for connectors within normal production tolerances. The crosstalk performance of plugs on terminal equipment leads is particularly variable. Consequently, pre-compensating in the plug as shown in Figure 4(c) or providing tunable socket compensation as shown in Figure 4(b) can provide

a significant performance improvement in these circumstances.

Fig 4(d) illustrates another alternative where the crosstalk compensation is provided by a special connector module 26 which includes tunable compensatory capacitances C_1, C_2. Such a module allows existing systems to be upgraded to compensate for existing, inherent connector crosstalk. In this example, the capacitances C_1, C_2 can be tuned to compensate for inherent crosstalk which otherwise arises in the plug 10 and socket 20 together with the module 26.

Fig 4(e) illustrates an alternative embodiment which may also be used to upgrade existing systems. In this case, a special cable connector 27 is adapted to introduce a known amount of compensatory crosstalk. This is achieved by altering the signal line positions over length l as shown.

Fig 4(f) illustrates a more sophisticated embodiment in which compensatory crosstalk is facilitated by crosstalk circuits X_1 and X_2. The circuits can contain active components which may be driven via external control inputs CTRL1, CTRL2 respectively to provide more selective crosstalk compensation. For example, if the level of crosstalk is continuously monitored, the control inputs CTRL1, CTRL2 may take the form of negative feedback inputs to control components such as varicap diodes to vary automatically the level of crosstalk compensation correspondingly.

The circuitry may include inductances which are selectively coupled at higher frequencies. If the inherent crosstalk is different between the signal line pairs (eg. because the signals are coded in different ways and transmitted at different frequencies), then the circuitry may require to allow more compensatory

crosstalk in one direction than in the other between the signal lines.

The invention may be extended by analogy to enable crosstalk compensation between more than just two pairs in multi-line data connectors. Where further crosstalk compensation is desired, it will generally be preferable to start by providing compensation between the lines having the next worse inherent crosstalk and then progressively provide further compensation between the affected lines until the desired level of crosstalk attenuation is reached for all the lines.

It will be appreciated that the invention is applicable to data connectors without regard to the particular shape of the connector (ie. whether the connector is circular or rectangular or any other shape in axial cross-section) or to the disposition of the conductors within the connector (ie. whether the conductors are wound around a circular core, spread out side by side in line or otherwise).

Fig 5 shows a data connector plug assembly 10 adapted to provide crosstalk compensation between line pairs in a conventional data line 11. In this example, the data cable 11 is passed through a strain relief member 12. The outer sheath of the cable 11 is stripped until the cable jacket protrudes from the front of the strain relief member 12 by around 2mm and the individually insulated conductor lines AA′-DD′ are laid out flat and inserted through the holes in the lower section 13 of the plug adapter 13,14 in the order C′C AB′BA′D′D as indicated by the colour coding shown in the drawing. The upper section 14 of the plug adapter 13,14 is then clipped into position to hold the cable in place. Pairs C′C, B′B and D′D are then given a half twist to bring them into the correct polarity order for

terminating. The adapter 13,14 is then inserted into the modular plug 15 and the lines are terminated in the normal way by insulation displacement contacts in the plug 15.

Crosstalk which would otherwise be introduced by laying the pairs in the conventional order the whole length of the connector 10 in both the adapter 13 and in the modular plug 15, is effectively cancelled by laying the lines C'C, B'B and D'D in reverse polarity order over the length of the adapter 13, introducing the half twists and then laying the lines in the conventional order over the remaining length of the connector in the modular plug 15. This arrangement is particularly advantageous as the connector otherwise uses normal, unmodified components. No special changes to the conventional components such as the insulation displacement contacts, plug adapter 13, 14 or plug 15 are required.

Fig 6 is a schematic drawing of the data connector cable 11 with connectors 10 at each end, both adapted to provide crosstalk compensation.

The effectiveness of this solution is confirmed by the measurements for near-end crosstalk attenuation in Tables 1 & 2 below which compare the results without and with crosstalk compensation.

Table 1 (Without Compensation)
NEXTA in dB between line pairs

Frequency MHZ	CC'-AA'	CC'-BB'	CC'-DD'	AA'-BB'	AA'-DD'	BB'-DD
1	75.6	85.0	100.4	68.5	75.5	84.0
4	63.8	73.3	88.2	56.7	63.8	72.4
10	55.9	65.6	80.3	48.9	56.0	64.7
16	53.1	62.8	77.2	46.1	53.2	61.9

Table 2 (With Compensation)
NEXTA in dB between line pairs

Frequency MHZ	CC'-AA'	CC'-BB'	CC'-DD'	AA'-BB'	AA'-DD'	BB'-DD
1	83.7	81.9	102.6	76.7	83.1	87.4
4	71.8	70.2	89.9	64.8	70.8	76.1
10	63.8	62.4	82.1	56.9	62.9	68.3
16	60.8	59.5	79.1	54.1	60.1	65.5

In some instances, a slight degradation in performance appears (eg. CC'-BB'), but overall there is a significant improvement with minimum attenuation improved from 48.9dB to 56.9dB at 10MHz in the worst case (AA'-BB'), and with crosstalk attenuation for other pairs improved by from 2 to 8dB at the same frequency.

Alternatively, or additionally, it is possible to adapt the socket assembly into which a plug assembly 10 (such as that shown in Figure 5 or the like) is to be connected so that crosstalk compensation is provided in the socket assembly. The principles of various ways of acheiving this have already been illustrated schematically, for example, in Figs 4(a), (b) and (f).

Fig 7 illustrates (not to scale) a practical implementation of the printed circuit shown in the example of Fig 4(a). Fig 7 shows the disposition of contacts on part of a printed circuit board (PCB) 25, as used in a conventional data communications patch panel, which has been modified to provide crosstalk compensation.

The PCB has contacts 23 on the right to which the incoming data line (not shown) is connected. Tracks 22 (one DD is numbered) are provided between these contacts 23 and corresponding contacts 21 in the area 24 to the left of the PCB where a conventional data jack (eg. RJ45

- not shown) is mounted so as to receive a data plug assembly (such as that shown in Fig 5 - whether modified according to the present invention or not). The tracks 22 between each corresponding pair of contacts 23, 21 are positioned to provide the desired crosstalk compensation between lines A'B, B'A, CA and D'A over track lengths $l_{A'C}$, $l_{B'A}$, $l_{C'A}$ and $l_{D'A}$ correspondingly as shown. It will be apparent that this arrangement is potentially equivalent in effect to the swapping of position of lines D & D', B & B' and C & C' in the modified plug assembly 10 of Fig 5.

As shown, crosstalk compensation can be acheived, therefore, without any need for conducting tracks 22 on the PCB 25 to cross over each other. A socket assembly with modified PCB 25 as in Fig 7 also has the advantage that no alteration is required to the conventional data connector component (ie. to the RJ45 jack) itself.

CLAIMS

1. A communications data connector comprising first and second signal lines for carrying differential pulse coded data signals, and at least one further signal line, characterised in that the connector further comprises

crosstalk compensation means provided between the first signal line and the further signal line; the crosstalk compensation means being such as to enable the introduction of compensatory crosstalk from the first signal line to the further signal line to counteract inherent crosstalk otherwise introduced between the second signal line and the further signal line.

2. A communications data connector according to claim 1 wherein the crosstalk compensation means comprises a section of the first signal line positioned in close proximity to the further signal line over a length selected to enable the introduction of said compensatory crosstalk.

3. A communications data connector according to claim 1 wherein the crosstalk compensation means comprises a reactive element connected between the first signal line and the further signal line.

4. A communications data connector according to claim 3 wherein the reactive element comprises a capacitance.

5. A communications data connector according to either claim 3 or claim 4 wherein the reactive element is tunable.

6. A communications data connector according to any preceding claim in which the connector comprises a communications data socket or plug.

7. A communications data connector comprising a first pair and a second pair of signal lines for carrying differential pulse coded data signals, characterised in that the connector further comprises

first crosstalk compensation means provided between a first line of each pair; and

second crosstalk compensation means provided between the second line of each pair;

the crosstalk compensation means being such as to enable the introduction of compensatory crosstalk from each line of the first pair to the corresponding line of the second pair to counteract inherent crosstalk otherwise introduced from each line of the first pair to each other line of the second pair.

8. A communications data connector according to claim 7 in which the crosstalk compensation means are further adapted to enable the introduction of compensatory crosstalk from each line of each pair to the corresponding line of the other pair to counteract inherent crosstalk otherwise introduced from each line of either pair to each other line of the other pair.

9. A communications data connector according to either claim 7 or claim 8 further comprising third and fourth pairs of signal lines for carrying differential pulse coded data signals further characterised in that crosstalk compensation means are provided by swapping the positions of the lines in each of the second pair,

the third pair and the fourth pair over a selected length of the connector.

10. For a communications data connector having first and second signal lines, and at least one further signal line, a method of compensating for inherent crosstalk introduced between the second line and the further line, comprising the steps of

assessing parameters characteristic of the inherent crosstalk between the second line and the further line under desired operating conditions;

providing on the first line, a complementary signal, matching, but of opposite polarity to the signal on the second line; and

providing a crosstalk compensation path between the first and the further lines to enable the introduction of compensatory crosstalk from the first line to the further line to counteract the inherent crosstalk.

11. A method of compensating for crosstalk according to claim 10 in which the crosstalk compensation path is provided by positioning the first line in close proximity to the further line over a length selected to enable the introduction of said compensatory crosstalk.

12. A method of compensating for crosstalk according to claim 10 in which the crosstalk compensation path is provided by coupling a reactive element between the first line and the further line.

13. A method according to claim 12 in which the coupling is provided by a capacitive element.

14. A method according to any one of claims 10, 11, 12 or 13 including the further step of tuning the crosstalk compensation means to provide a desired level of crosstalk compensation.

Fig. 1.

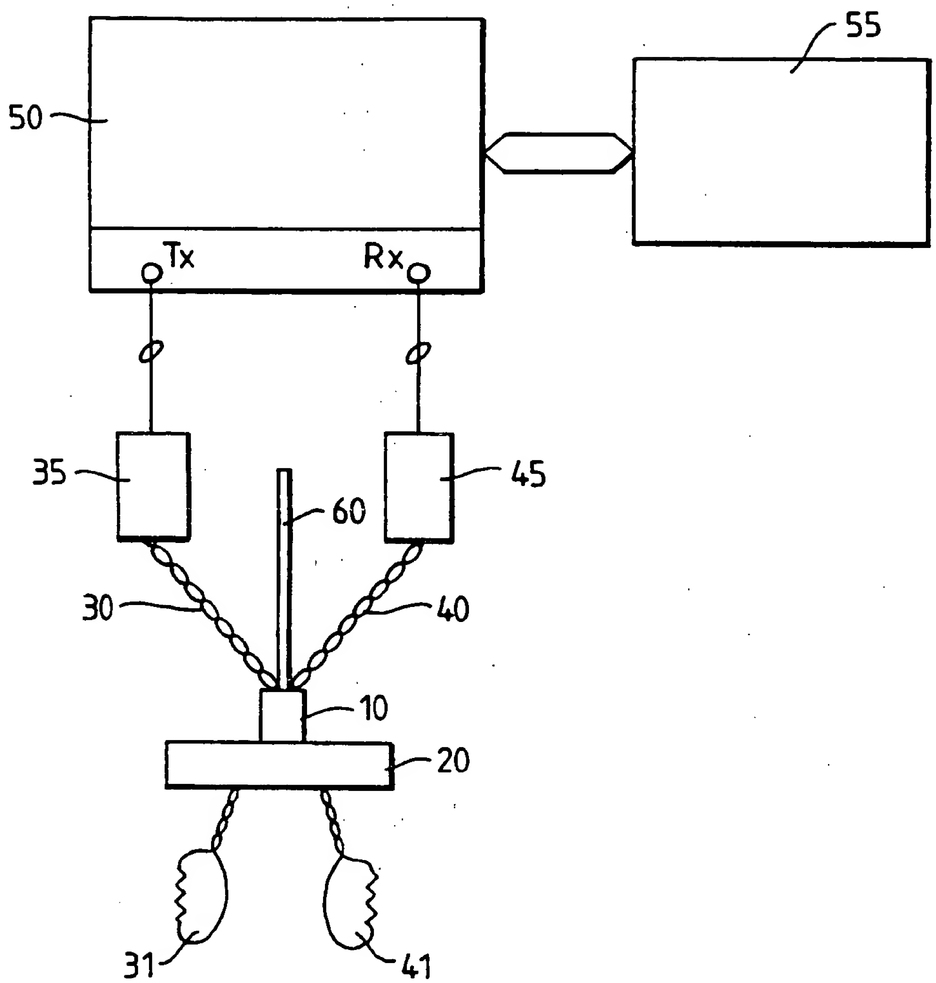


Fig.2(a).

DATA JACK UNIT (DJU)
CONNECTION SCHEMATIC

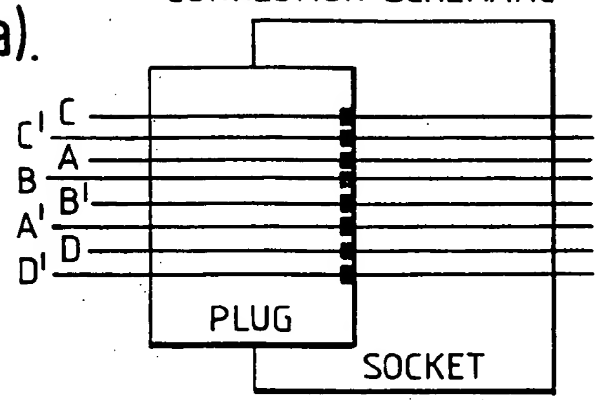


Fig.2(b).

EQUIVALENT ELECTRICAL CIRCUIT FOR LINES AA' BB' WITHOUT COMPENSATION

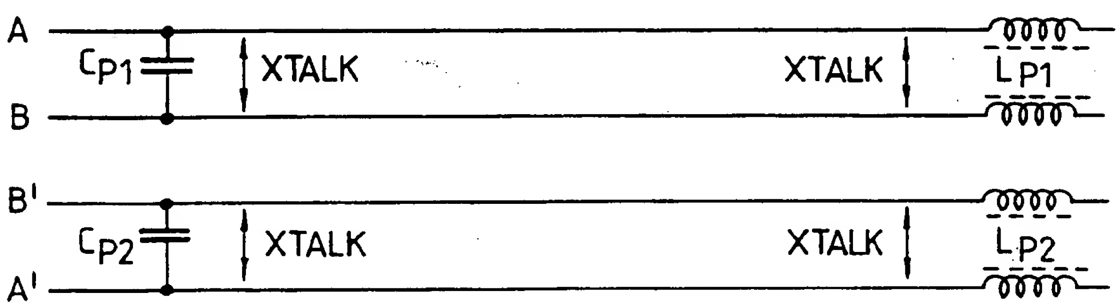
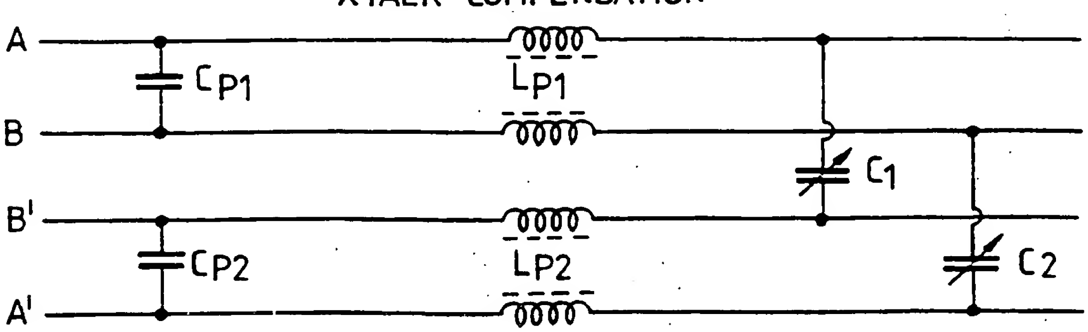


Fig.2(c).

EQUIVALENT ELECTRICAL CIRCUIT FOR LINES AA' BB' WITH FIRST ORDER XTALK COMPENSATION



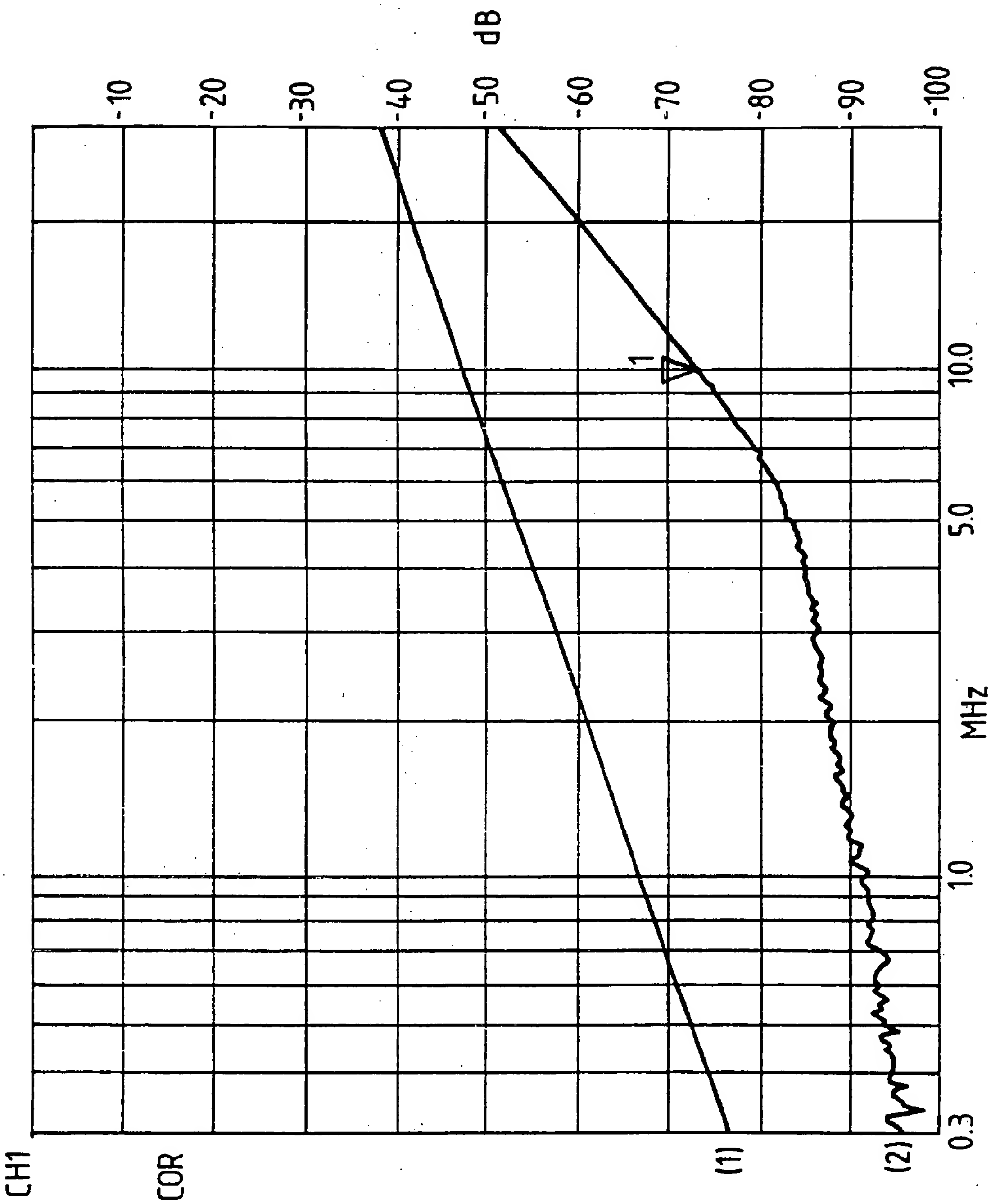


Fig. 3.

Fig.4(a).

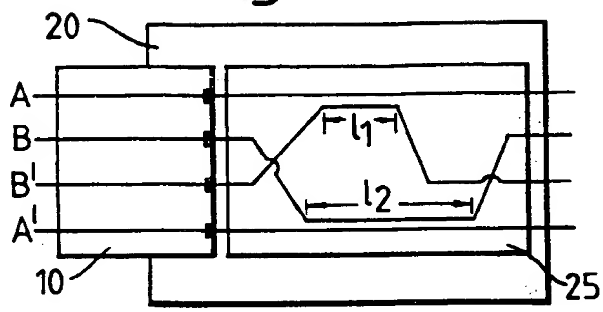


Fig.4(b).

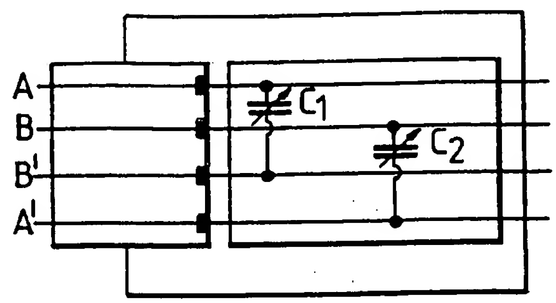


Fig.4(c).

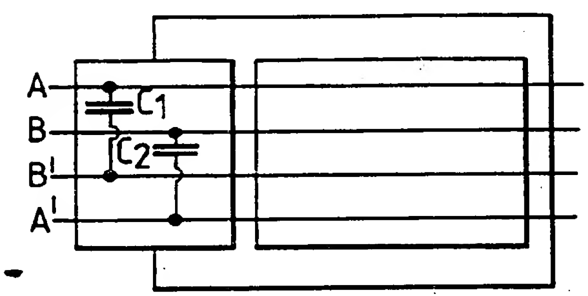


Fig.4(f).

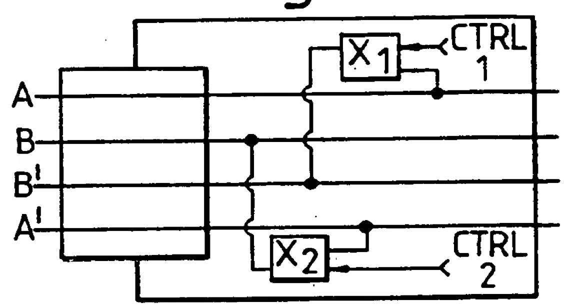


Fig.4(d).

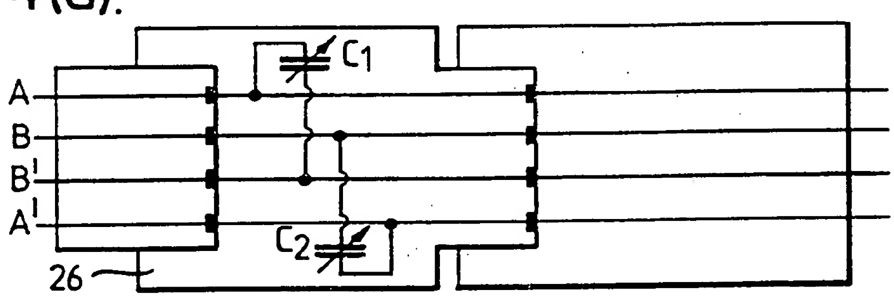
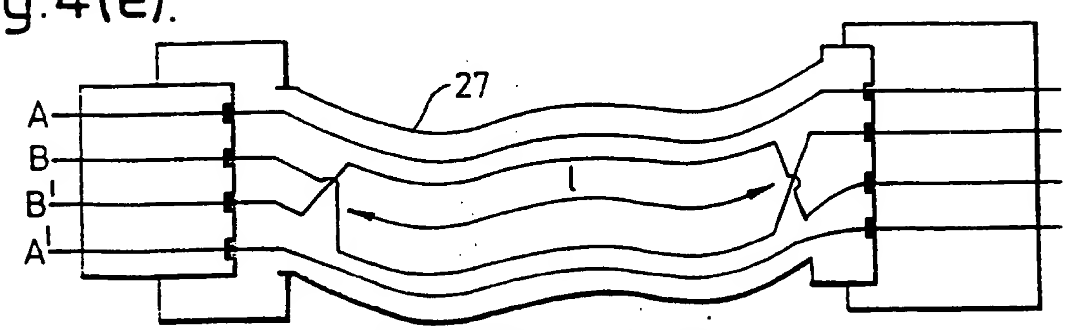


Fig.4(e).



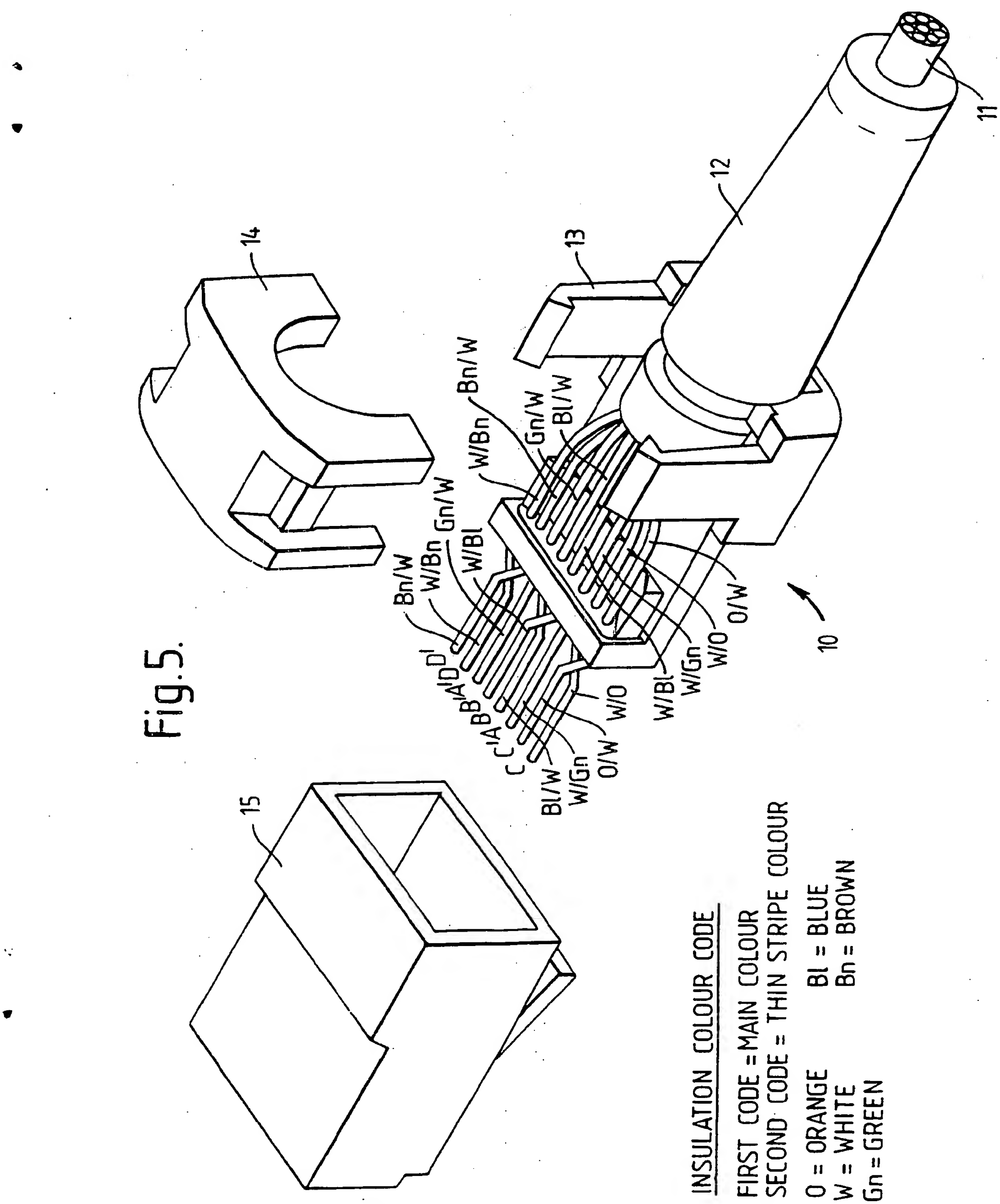

10
11
12
13
14
15
Bn/W
Gn/W
Bl/W
W/Bn
Gn/W
W/Bn
W/Bl
Bn/W
O/W
W/O
W/Gn
W/Bl
W/O
O/W
W/Gn
Bl/W
D'
D
A'
A
B'
B
C'
C
INSULATION COLOUR CODE
FIRST CODE = MAIN COLOUR
SECOND CODE = THIN STRIPE COLOUR
O = ORANGE
W = WHITE
Gn = GREEN
Bl = BLUE
Bn = BROWN

Fig.5.

Fig.6.

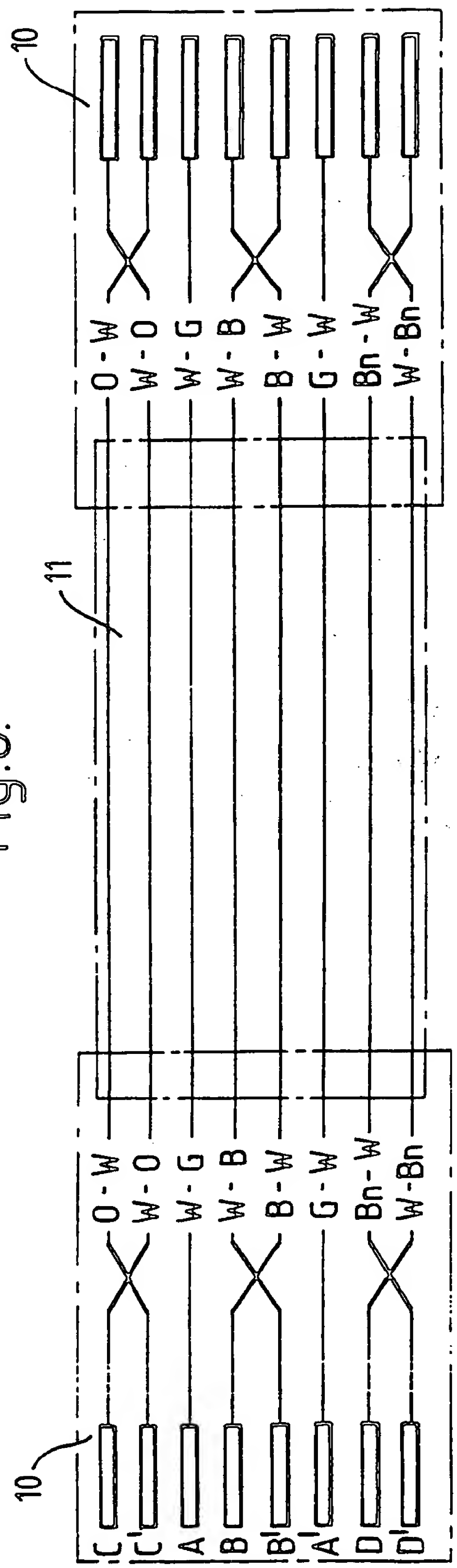
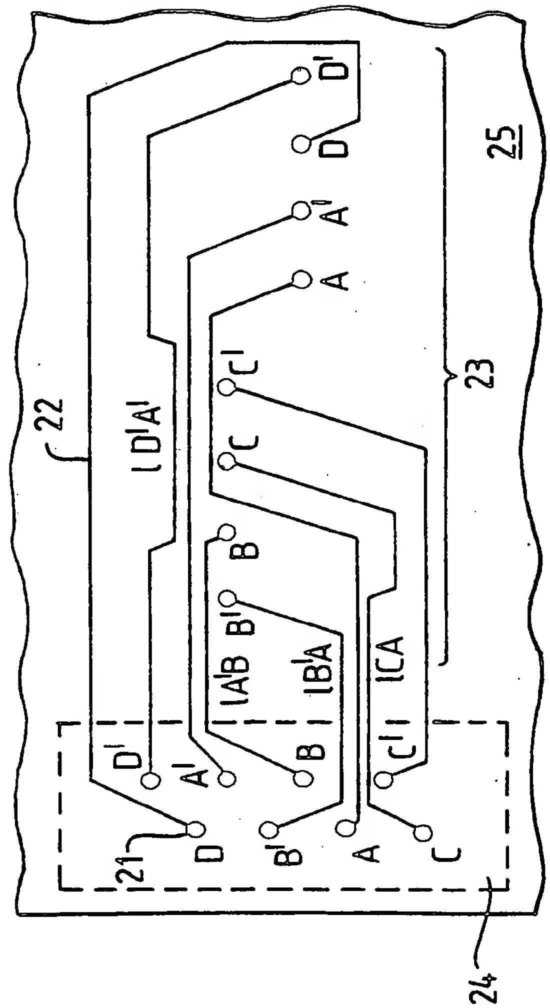

10
11
O-W
W-O
W-G
W-B
B-W
G-W
Bn-W
W-Bn
C
C'
A
B
B'
A'
D
D'

Fig.7.


21
22
23
24
25
A
A'
B
B'
C
C'
D
D'
ID'A'
IA'B
IB'A
ICA

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 93/01801

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 H04B3/32

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 H04B H01R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE,A,31 45 039 (HITACHI) 16 September 1982 see abstract see page 7, line 8 - line 29 see page 9, line 4 - page 10, line 2 see figures 2,4 ---	1,2,7,8, 10,11

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
26 November 1993	07. 12. 93

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax (+ 31-70) 340-3016	Lydon, M

INTERNATIONAL SEARCH REPORT

Intern al Application No
PCT/GB 93/01801

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PROCEEDINGS OF 1988 IEEE INTERNATIONAL SYMPOSIUM ON ELECTROMAGNETIC COMPATIBILITY 2-4 August 1988, NEW YORK (US) pages 322-326; A.GOTTWALD and W.RUPP: "SUPPRESSION OF SPURIOUS SIGNALS IN MULTIPLE-WIRE TRANSMISSION CIRCUITS BY COMPENSATION METHODS" see page 323, right column, line 36 - page 324, left column, line 17 see figure 3 -----	1,7,10

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 93/01801

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A-3145039	16-09-82	JP-A- 57084149	26-05-82
		FR-A- 2498852	30-07-82
		GB-A- 2089122	16-06-82